C) Amendments to the specifications:

(page 1)

A Universal Millimeter-Wave Housing with Flexible End Launchers

This is a divisional patent of the application serial number 09/351,362, filed by Yi-Chi Shih, Long Q. Bui and Tsuneo C. Shishido on 07/12/99, now U.S. Patent number 6,363,605 issued on 04/02/2002.

~~ABSTRACT OF DISCLOSURE~~

~~A precision non-symmetrical L-shape waveguide end-launching probe for launching microwave signals in both vertical and horizontal polarizations is disclosed. The L-shape waveguide probe is in a form of thin plate, has a first arm and a second arm, and is precisely fabricated and attached to one end of the central metal pin of a feedthrough. The feedthrough is installed to an aperture formed in a major wall of the universal conductive housing to achieve hermetic sealing. The L-shape waveguide probe is aligned by means of a specially designed alignment tool so that long axis of the second arm is always perpendicular to the broad walls of the output waveguide, which is mounted to the universal housing with the broad walls of the output waveguide either horizontally or vertically. Hence, in this invention, an end-launching arrangement using the L-shape probes that could yield a flexible waveguide interface either in horizontal polarization or vertical polarization is provided. The impedance matching and frequency bandwidth may be adjusted by controlling dimensions and positions of the L-shape probe. A plurality of the thin plate L-shape waveguide probes is fabricated by a micro lithography and etching method to ensure reproducibility and reliability. By incorporating with an impedance transformation section having a slot, broad band performance is achieved using the L-shape waveguide probe.~~

(page 4, paragraph 2)

In US patent application No. 09/351,362, filed by Yi-Chi Shih, Long Q. Bui and Tsuneo C. Shishido on 07/12/99, now U.S. Patent number 6363605, a universal conductive housing for different millimeter wave MMICs with a feedthrough has been disclosed. A plate shape waveguide probe, which is symmetrical and fabricated by a micro lithography and etching method, is aligned using a precision alignment tool with respect to a pin of the feedthrough and welded or soldered by a miniature solder. The uniformity and reliability of the waveguide transition has been improved using the structure described in the US patent number 6363605 ~~application No. 09/351,362~~. However, since the waveguide probes described in that invention are symmetrical and aligned perpendicular to the major exterior wall of the universal conductive housing and perpendicular to the broad walls of the waveguide, the electric field polarization is always perpendicular to the major exterior wall of the universal conductive housing. Hence, the input/output waveguide interface always forms a 90 degrees angle with respect to the normal of major walls of the universal conductive housing. In many applications, it is very desirable and sometimes necessary to integrate components in-line with the main housing at the waveguide input/output interfaces, i.e. the long axis of the input/output waveguide interface should form a near zero degree angle with respect to the normal of major walls of the universal housing. This requirement thus creates a need to have a new arrangement and structure for the waveguide probe. Furthermore, it is preferable to have a waveguide transition with operating frequency range broader than the previous structure involving symmetrical waveguide probes.

(page 5: BRIEF DESCRIPTION OF THE DRAWINGS)

Fig. 1(a) is a schematic cross-sectional view of the prior art feedthrough for use with the housing shown in Fig. 1(b). Fig. 1(b) is a schematic top view of a conductive housing for MMICs. ~~With the prior art waveguide probe (38), electric field polarization of the microwave signals excited is always perpendicular to the major exterior wall (28a).~~ Fig. 1(c) is a prior art symmetrical waveguide probe.

Fig. 2 is a schematic top view of the L-shape non-symmetrical waveguide probe with the first arm ~~(41)~~ and the second arm ~~(42)~~ according to this invention.

Fig. 3 (a) is a schematic view of the conductive housing with an L-shape waveguide probe ~~(40). Using the L-shape waveguide probes provided in this invention, microwave signals with electric field polarizations parallel to the major exterior wall (28a) can be easily obtained~~. Fig. 3(b) is a schematic view of a universal launcher adapter ~~(51')~~ for the excitation of microwave signals with vertical electric field polarization. Fig. 3(c) is a waveguide section for receiving and propagation of microwave signals excited by the L-shape waveguide probe. Fig. 3(d) is a universal launcher adapter rotated by 90 degrees for the excitation of microwave signals with horizontal electric field polarization Fig. 3(e) is a schematic front view of the universal launcher adapter showing a slot ~~(54a)~~ formed in the through channel for impedance transformation.

Fig. 4(a) is a schematic cross-sectional view of the metal substrate with two photoresist layers coated on the two surfaces for the fabrication of non-symmetrical L-shape waveguide probes. Fig. 4(b) is a top view of the first photomask used. Fig.4(c) is a cross sectional view of the substrate after etching of the exposed regions. Fig. 4(d) is a top view of etched waveguide probes connected by fine brass wires ~~(66, 66b')~~.

Fig. 5 is a schematic partial view of the conductive housing ~~(20)~~, L-shape waveguide probe ~~(40)~~ in a precision alignment tool ~~(80)~~ for aligning and mounting the L-shape waveguide probe to central metal pin of the feedthrough installed in the conductive housing.

(DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS)

(page 7, paragraph 1)

Referring to Fig. 1(a), there is shown according to the prior art method an RF feedthrough (1) consists of a central metal pin (2), hereinafter called pin, which is partly enclosed with glass (3) and a metal ring (4). Diameter (5) and length (6) of first part (7) of the pin and inner diameter (8) of the metal ring may be designed according to known prior art method so that when installed to a conductive housing, the impedance of the RF feedthrough can be matched with the characteristics impedance of the MMIC. For instance, a pin with a diameter of 10 mil may be used. The outer diameter (9) of the metal ring is about 10 - 20 micrometers smaller than the main diameter (21) of the bores (22) shown in Fig. 1(b) of a universal conductive housing. Furthermore, the length (10) of the metal ring (4), or the second length of pin, is selected to be substantially equal to the major depth (23) of the bores as shown in Fig. 1(b). The third length (11) of the pin is selected so that contact attachment or wire bonding can be easily performed to the MMIC (24) of Fig. 1(b).

(page 7, paragraph 3 – page 8, paragraph 1)

To form a waveguide transition according to US patent ~~application 09/351,362~~ number 6363605, a plate shape waveguide probe (38), which is symmetrical with respect to the long axis (37) of pin, is attached to the end of the first part of the pin (7). As shown in Fig. 1(c), the waveguide probe (38) according to the previous invention is symmetrical with respect to the axis (15) of the slot (16). The symmetrical waveguide probe is characterized by a major probe wall (30). Although the plate shape waveguide probe (38) may be fabricated by mechanical machining methods, a micro lithography and etching method may be preferably used.

(page 8, paragraph 2)

The waveguide probe (38) is aligned and soldered or welded to the end of the first part (7) of the pin extending outside the housing, as shown in Fig. 1(b). After this, a

section of waveguide (31), having two broad side walls (32,33) and an end wall (34), is aligned and mounted to the exterior major wall (28) of the housing (20). It is noted that a portion of the broad side wall (32) of the waveguide has been removed whereas the other broad side wall (33) is intact, so that when the section of waveguide is mounted and attached to the housing, a complete waveguide cavity (35) is formed. The end wall (34) of the section of waveguide is adjusted so that the distance (36) between the end wall (34) and the central line (37) of the waveguide probe is substantially equal to a quarter of the wavelength of the microwave signals (39) to be propagated.

(page 8, paragraph 3)

In most of the prior art methods, cylindrical or conical beads are used as the waveguide probes in waveguide transition. These beads are symmetrical and have certain performance limits. In addition to the higher cost for the fabrication, it is rather difficult to attach the cylindrically- or conically-shaped beads to ends of fine metal pins, especially for high frequency coaxial/waveguide transitions. Since the launching efficiency and frequency response of a waveguide/coaxial transition are determined by the shape, dimensions and position of the waveguide probe within the waveguide, it is more difficult to achieve microwave transitions using the prior art cylindrical or conical beads. Even the plate shape waveguide probe disclosed in US patent ~~application No. 09/351,362, filed 07/12/99~~ number 6363605 is symmetrical with respect to the central axis. Hence, when the prior art waveguide probe is mounted to the pin of a feedthrough, the waveguide probe is always symmetrical with respect to central line (37).

(page 9, paragraph 1)

According to a first embodiment of this invention, a non-symmetrical waveguide probe (40) as shown in Fig. 2 is provided to improve the control of polarization and bandwidth. The non-symmetrical waveguide is very different from the prior art symmetrical waveguide probe both in geometrical shape and in the characteristics of electrical excitation. The non-symmetrical waveguide probe (40) is made of a thin plate of metals or alloys such as brass or copper. Thickness of the plate for the non-

symmetrical waveguide probes is in the order of 10 mils. The waveguide probe consists of a first arm (41) and a second arm (42). The long axis (41a) of the first arm is arranged to be substantially perpendicular to the long axis (42a) of the second arm so that they form an L-shape non-symmetrical waveguide probe. A slot (44) is formed in the central left portion of the first arm. Width (45) of the slot is slightly greater than the diameter (5) of pin (7) shown in Fig. 1(a) whereas the length (46) of the slot is less than the length (6) of the first part on the pin (7). Corner (43) of the overlapped region between the first arm and the second arm is rounded whereas left-hand corners (47, 48) of the first arm are also rounded in order to improve the launching performance of the microwave signals. The L-shape waveguide probe is also characterized by a first broad wall (49) and a second broad wall (not shown) which are parallel to the long axis (41a) and the long axis (42a).

(page 10, paragraph 1 - page 11, paragraph 1)

To form a microwave end launcher with controlled polarization and improved frequency bandwidth, the non-symmetrical waveguide probe (40) is mounted at one end (7) of the pin of a feedthrough (1), as shown in Fig. 3(a). The feedthrough is mounted in a major wall (28) of a conductive housing (20). The conductive housing has two broad walls (20b), a major exterior wall (28a) and is formed by metals or alloys. There are threaded holes (20a) for the mounting of a waveguide section. The long axis (42a) of the second arm (40) of an L-shape non-symmetrical waveguide probe is aligned to be substantially parallel to the major exterior wall (28a). Inside the conductive housing there are MMICs and components. To facilitate the mounting of a waveguide section (50, in Fig. 3(c)) for receiving and guiding the microwave signals excited by the non-symmetrical waveguide probe, a universal launcher adapter (51', Fig. 3(b) or 51 in Fig. 3(d)) is provided. The universal launcher adapter is constructed by metals, alloys or plastic materials with layers of metals coated on all walls. A through channel (52) is arranged in the center of the broad wall (53). The through channel is defined by two long walls (55), defining a height (55a), and two short walls (54), defining a width (54a). Both the width (54a) and height (55a) of the through channel are selected to be the same as that for the inner cavity (58) of the waveguide section (50) used, which has two broad

waveguide walls (56). It is noted that the universal launcher adaptor (51) is similar to the universal launcher adaptor (51') except that the long walls (55) for (51) are perpendicular the long walls (55) of (51'). By providing a precision slot (~~54a~~ 54s in ~~Fig. 3(d)~~ Fig. 3(e)) in one of the two short walls, the universal launcher adapter also serves as a universal impedance transformation section. Another universal lunched adapter (51'') may also be connected to the same universal conductive housing.

(page 11, paragraph 2)

There are four screw holes (51a), one in each corner of the broad wall (53) of the universal launcher adapter. Positions of the four screw holes (51a) are arranged to match the positions of four screw holes (50a) in the flange (50b) of the waveguide section (50) for mounting purpose. There are additional four screw holes (51b, 51b') in the universal launcher adapter (51). Positions of two (51b) of the four screw holes are arranged to match the positions of two screw holes (20a) in the major wall (28) of the conductive housing (20) when mounted in one position. Positions of two other screw holes (51b') are also arranged to match the positions of the two screw holes (20a) in the major wall (28) of the conductive housing (20) when mounted in the other position (see Fig. 3(d)).

(page 12, paragraph 2)

Alternately, if the L-shape waveguide probe (40) is rotated by 90 degrees with respect to the axis of pin (7) so that the second axis of the second arm is parallel to the broad wall (20b) and the major exterior wall (28a), the polarization of the excited microwave signals will be different. To guide the microwave signals, the universal launcher adapter (51') is also rotated by 90 degrees as shown in Fig. 3(d) to form a new end launcher (51). When the universal launcher adapter is mounted to the major wall (28), screw holes (51b) will be aligned to screw holes (20a). The polarization of the excited microwave signals is still perpendicular to the long walls (55) of the through channel. Hence, when the waveguide section (50) is mounted to the universal launcher adapter, with the cross-section of the cavity of the waveguide coinciding the through channel (52), microwave signals with polarization substantially perpendicular to the

broad walls (56) of the waveguide section can be obtained and propagated. The electric polarization is now horizontal with respect the broad walls, which are substantially parallel to the reference plane, of the universal conductive housing. It is noted that, by providing a precision slot (~~54a~~ 54s) in one of the two short walls, the universal launcher adapter also serves as a universal impedance transformation section.

(page 13, paragraph 1)

In order to achieve high efficiency excitation of microwave signals, as shown in Fig. 3(a), it is preferable to mount the L-shape waveguide probe so that the distance (57) between the major exterior wall (28a) and the long axis (42a) of the second arm in Fig. 2 is substantially equal to one quarter of a wavelength of the microwave signals to be excited and propagated. This can be achieved by designing the length (41b in Fig. 2) of the first arm to be slightly than one quarter of the wavelength.

(page 14, paragraph 2 – page 15, paragraph 1)

Referring to Fig. 4(a) - (d), which provide flow diagrams of main fabrication steps and photo mask patterns, the fabrication of precision L-shape waveguide probes according to a second embodiment of this invention is performed as follows. As shown in Fig. 4(a), a brass substrate (60) with a thickness of about 10 mil is first solvent cleaned and baked dry. The thickness of the substrate 10 mil is selected to be the same as the diameter of central pin (7 in Fig. 3(a)) to facilitate the subsequent attachment of the waveguide probe to the pin. Although the value of 10 mil is given as an example for the substrate thickness, substrates with thickness other than 10 mil such as in a range 50 micrometers to 400 micrometers may be used. A first photoresist ~~footrests~~ layer (61) of a thickness about 1-2 micrometers is then applied on the front surface and a second photoresist ~~footrests~~ layer (62) is applied on the back surface of the brass substrate. After a soft baking at 90°C for 10 minutes, the first photoresist layer (61) on the front surface is exposed to UV light through a first photo mask (63) while the second photoresist layer on the back surface is unexposed. It is noted that the purpose of the second photoresist layer is for protection of the substrate during subsequent etching. The first photo mask contains

opaque regions (64) and transparent regions (65). These regions are designed so that a plurality of waveguide probes can be formed on a brass substrate in one fabrication run. A positive tone photoresist such as AZ-1820 from Shipley Company, Massachusetts may be used. Since AZ-1820 is a positive tone photoresist, the opaque regions (64) define the dimensions and shape of the non-symmetrical waveguide probes. According to this invention, it is preferred to connect all of the waveguide probes together electrically to facilitate the electrodeposition of Au or Ag layer. Fig. 4(b) shows a top view of the patterns on the first photomask used. To simplify the explanation, the first photomask provided contains nine non-symmetrical waveguide probe patterns (40a). Each of the waveguide probe patterns is connected electrically to adjacent four waveguide probe patterns by fine wire patterns (66a, 66b). The purpose of the fine wire patterns is to create fine brass wires after etching to provide electrical connection, to facilitate the electrodeposition of Au or Ag. Furthermore, a slot pattern (67a) is created in each waveguide probe pattern (40a). Hence after etching, a slot (67 in Fig. 4(e)) will be created in each non-symmetrical waveguide probe. This slot will allow the attachment of a waveguide probe to the end of the first part of pin (7) of the feedthrough as shown in Fig. 3(a). It is noted that the width (77a) of the slot pattern (67a) is selected so that after etching, the width (77 in Fig. 4(d)) of slot in the formed waveguide probe is slightly greater than the diameter of the pin (7) shown in Fig. 3(a).

(page 15, paragraph 2 - page 16, paragraph 1)

After development of the photoresist on the front surface, the patterns on the first photomask shown in Fig. 4(b) is transferred onto the first photoresist layer with exposed brass regions and unexposed brass regions. The brass substrate with the photoresist patterns is then baked at 110°C for 20 minutes. After this hard baking, exposed brass regions are etched by immersing the substrate in an etching solution containing ferric chloride, ~~FeCl3~~ $FeCl_3$. Typical time required to etch through the 10 mil thick brass is about two minutes at room temperature. It is noted that the etching time may be reduced by agitating the solution or by increasing the solution temperature. It is further noted that the final dimensions of each waveguide probe are determined firstly by the dimensions of

patterns in the photomask and secondly by the etching of the brass substrate. Since the dimensions of each prior art waveguide probes must be controlled precisely during the mechanical machining, the time required is long and the fabrication cost is high. Fig. 4(c) shows a cross-sectional view of the brass substrate after the etching. Here, L-shape waveguide probes (40) are created by the etching. For clarity, the fine brass wires and fine photoresist patterns defining the fine brass wires (66, 66b') given in Fig. 4(d) are not shown. After this, the remaining photoresist patterns (69) and the photoresist (62) on the back surfaces of the waveguide probes are removed by immersing the substrate in acetone. This is followed by a rinse in de-ionized water. Fig. 4(d) is a schematic top view of the waveguide probes fabricated and before separation. It is noted that each L-shape waveguide probe (40) is connected to adjacent waveguide probes by fine brass wires (66, 66b'). It is noted that one slot (67) has been created for each L-shape waveguide probe for alignment purposes. A layer of gold is now plated over the surfaces of each waveguide probe while all of the waveguide probes are still connected together electrically. This is done by attaching one part of the connected waveguide probes to the cathode of an Au electrodeposition system (not shown) to deposit an Au layer with a thickness of 1-5 micrometers. The purposes of the Au layer are to increase the surface conductivity of the waveguide probes and to facilitate the attachment to the pin. After the Au deposition, the waveguide probes are rinsed in de-ionized water and dried. The fine brass wires (66, 66b') connecting adjacent waveguide probes are finally cut to isolate one waveguide probe from the others.

(page 16, paragraph 2)

During the etching of the exposed substrate regions to form the L-shape waveguide probe, undercutting (U in Fig. 4(c)) is unavoidable. In order to increase the reproducibility of dimensions, it is preferred to reduce the amount of the undercutting. One method to reduce the undercutting is to carry out etching from both the front surface and the back surface of the substrate (60). To achieve this, a second photomask (not shown) is prepared to expose selectively the second photoresist layer (62). Patterns on the second photomask are similar to those on the first photomask, except that the ones on the

second photomask are mirror images of the second photomask. The alignment of the second photomask against the substrate will be carried out in a special mask aligner (not shown) which allows the precise alignment of patterns on the second photomask to the patterns of the first photoresist layer created by the first photomask. Hence, after development, the patterns (not shown) on the back surface aligned precisely to the patterns (64, 65 Fig. 4(a)) on the front surface. The alignment of the patterns on the second photomask may be carried out after the patterns of the first photoresist layer have been developed. After the exposure of the second photoresist layer to the ultraviolet light through the second photomask, the second photoresist is developed and baked. Etching can now be proceeded from both sides in order to reduce the undercutting. Since the etching time required for the etching from both the front surface and back surface of the substrate is about half of that required from the front surface alone, the undercutting will be about half of the undercutting (U) in Fig. 4(c).